PROCESS FOR PRODUCING SUPER HIGH BULK, LIGHT WEIGHT COATED PAPERS

FIELD OF INVENTION

The present invention relates to a process of manufacturing a high bulk, low weight paper product having stiffness and opacity comparable to heavier weight sheets, the process consisting of using a high level of groundwood containing sheet, coating with specifically formulated coatings then passing the paper web through two extended-nip calenders, using one nip for each side of the paper.

BACKGROUND OF INVENTION

Due to the continue increase in bulk postage rates, a significant demand has been created for lighter paper stock suitable for magazine use. As paper stock is made lighter, however, the problem of "show-through" and a limp "feel" arise substantially precluding use of such lighter paper in magazines, brochures, annual reports, advertising pieces, direct mail and like promotional materials, especially in high quality magazines.

Attempts to make lightweight, high bulk paper have been made utilizing higher levels of groundwood and coating the paper web with a coating formulated with higher level of kaolin and plastic pigments or by using coating that tends to be bulkier than conventional coating. See for example U.S. Patent Nos. 6,287,424, 6,332,953, and 4,749,445. U. S. Patent No. 5,283,129 discloses a high gloss lightweight paper stock that is coated with a pigment composition including delaminated clay, calcined clay and titanium dioxide, wherein up to about 5 parts by weight of hollow core opacifying plastic pigment may be substituted for the titanium dioxide. U.S. Patent No. 4,010,307 discloses a high gloss coated paper product comprising 70-95% calcium carbonate and from 5-

30% by weight of a non-film forming polymeric pigment having particles sized within the range of from 0.05-0.30 microns.

In papermaking the finishing operation may be a calendering process, in which the paper web is passed between the nips formed between or more pairs of rolls and the surface of the web is thereby flattened to form a smooth surface. Simultaneously, the thickness, or caliper, of the paper web is reduced and the web is densified. Bulk is inversely related to density, therefore when the density is increased, the bulk of the finished paper product will be reduced. Further attempts to make lightweight (24-40 pounds), high bulk coated paper have been made utilizing on-line hot soft calender, on-line supercalender, or off-line supercalender at reduced loading and nip number. *See*, for example, U.S. Patent Nos. 5,694,837, 5,750,259, 5,546,856, 5,400,707 directed to an apparatus for finishing a continuous sheet of paper; U.S. Patent No. 5,163,364, directed to a method for calendering a paper or cardboard web, and U.S. Patent Application No. 09/839,507, directed to high bulk paper. See also, Wikstrom, M. "Calendering of coated paper and board in an extended soft nip. Nordic Pulp & Paper Research J. no. 4, P289-298 (1997); Carlsson, et. al., "Influence of latex binder viscoelastic properties on the high temperature calendering runnability. 2002 TAPPI Coating Conference, P-457; and Moreau-Tabiche et al., "Wood containing paper pilot calendering – obtained results through supercalendering, soft nip calendering, and extended nip concept. TAPPI 2000 Coating Conference, P-245.

However, such attempts to make lightweight, high bulk paper utilizing lower than conventional supercalendering nip pressures have resulted in papers that generally have low gloss, usually well below a 75° TAPPI gloss of 40, namely less than 35. Such lower gloss paper is not acceptable for many publication purposes, such as magazines where lightweight high bulk paper, with high gloss and good print gloss is desired.

Thus, current practices to increase bulk of paper include using a higher level of groundwood containing base and coating with an easy-finishing coating (i.e., formulated with a higher level of kaolin and plastic pigments) then followed by supercalender at reduced loading and nip number. Analyzing current 30 pounds commercial samples indicates that the bulk of such paper is in a range of 1.7-1.9 mils.

The prior art does not teach a process of making high bulk, lightweight coated paper having high stiffness, opacity and brightness that may be used as a "low end" offset paper. Thus, there is a strong need of developing a lower weight sheet with benefits of higher stiffness and opacity that are comparable to that of a heavier weight sheet.

BRIEF SUMMARY OF THE INVENTION

The need apparent in the art is met by the present invention, which provides a process of making a 30 pounds/3300 square feet super high bulk, lightweight coated (LWC) paper having high stiffness, opacity and brightness that may be used as a "low end" offset paper, which process consists of using high level of groundwood containing sheet, blade coating with specifically formulated coatings, followed by calendering with two extended-nip calenders, one calender for each side of paper.

Our data shows that the process of the present invention produces a super high bulk LWC, with up to 22% bulk improvement over the highest current commercial sheet. The extended-nip calendered paper of the present invention exhibits better brightness and opacity, and equivalent or better printing performance, specifically in the print gloss performance, than supercalendered counterparts. The significantly higher bulk resulting from the use of two extended-nip calenders is largely due to better bulk preservation of the extended-

nip calender, that is, under an equivalent loading using two extended-nip calenders gives lower nip intensity than supercalender and hot soft calender.

Thus, an object of the invention is to provide a process for making a super high bulk, offset lightweight coated paper, comprising the steps of:

(a) creating a fiber furnish comprising mechanical pulp and chemical pulp;

(b) forming a paper web from the fiber furnish;

(c) removing water from said web;

(d) applying the coating formulation of the present invention

(e) calendering by passing the coated web through the nips of two extended-nip calenders, with each side of paper facing a heated roll and treated with one of said calender nips; whereby each calendering nip is formed by a calender roll having a surface temperature of at least 300° F and a backing shoe having a width of at least 30 mm, the nip providing loading of at least 1000 pounds per linear inch; and whereby the calendered paper has a caliper preservation greater than 75%.

Another object of the invention is to provide a process for making a 30 pounds/3300 square feet super high bulk, No. 5 offset lightweight coated paper.

Another object is to provide a furnish comprising at least 40% mechanical pulp, preferably 60% mechanical pulp, wherein the mechanical pulp portion comprises an equal blend of thermal mechanical pulp (TMP) and a conventional stone groundwood pulp, and wherein the remaining makeup is Kraft.

A further object of the present invention is to provide a process for making a super high bulk, offset lightweight coated paper, wherein the coating formulation is preferably applied using a blade coater or a metering size press.

Another object of the invention is to provide a process for making a super high bulk, offset lightweight coated paper, wherein the coating formulation consists of (i) a hollow plastic pigment; (ii) a kaolin pigment; (iii) a calcined kaolin clay; (iv) a titanium dioxide (TiO_2) pigment; (v) a synthetic latex binder; and (vi) a synthetic thickener (or a co-binder including carboxymethylcellulose (CMC) or acrylic acid based or associative based thickeners.

Another object is to provide a coating formulation wherein said hollow plastic pigment, in an amount of at least about 2% by weight, and preferably 3 to 5% by weight of the total amount of pigments.

Another object is to provide a coating formulation wherein said kaolin pigment is at least about 70% by weight, preferably 80-100% by weight of the total amount of pigment, and has a fine particle size distribution characterized by at least 85% of said particles are less than 2 microns and at least 50% of said particles are less than 0.5 microns, based upon particle count using a Sedigraph particle size analyzer, and wherein said kaolin pigment has a platy morphology characterized as both fine and coarse particles having a shape factor greater than 15, preferably 20-27.

Another object is to provide a coating formulation wherein said calcined kaolin is at least about 5% by weight of the total amount of pigment.

Another object is to provide a coating formulation wherein said TiO_2, in an amount of at least about 2% by weight and preferably 3 to 5% by weight of the total amount of pigment.

Another object is to provide a coating formulation wherein said synthetic latex is in a concentration of at least about 12 or more parts by weight of the total amount of pigment.

Another object is to provide a coating formulation wherein said synthetic thickener is in a concentration of at least about 0.05 or more parts by weight of the total amount pigment.

Another object is to provide a coating formulation which coating may also comprise precipitated calcium carbonate (PCC) or ground calcium carbonate (GCC).

Another object of the present invention is to provide a coating having a weight of at least 2.0 pounds per 3300 square feet, preferably 2.0 to 60 pounds per 3000 square feet, and most preferably 2.5 to 5.5 pounds. per 300 square feet, per side onto each surface of said web to form a coated web having a moisture content prior to calendering of at least 5.5%, preferably 6.5-8.0%, and most preferably 7.0%, the coating comprising a fine, platy kaolin pigment, a latex binder, and a thickener, said coated web having a caliper greater than 2.6 mils.

Another object of the present invention is to provide a process for making a super high bulk, offset lightweight coated paper, while preserving significantly more of the original bulk than traditional supercalender or hot soft calenders, the calendering step is carried out using two extended-nip calenders, wherein the calender is preferably a shoe nip calender (SNC), said shoe nip width being in the range of from about 40 mm to about 80 mm, and calendering temperature controlled at about 300° F to about 430° F, and nip loading at 1700-2400 pli.

Another object of the present invention is to provide a process for making a super high bulk, offset lightweight coated paper, wherein the finished coated paper has a basis weight of 28 to 38 pounds per 33 square feet and exhibits a 75° TAPPI gloss of 35% or above and a caliper of at least 2.15 mils.

Another object of the present invention is to provide a process for making a super high bulk, offset lightweight coated paper, wherein the LWC gives a 17-

27% higher caliper than that of a supercalendered 30 pounds/3300 square feet LWC and has improved brightness, opacity and printing gloss.

Another object of the present invention is to provide a process for making a super high bulk, offset lightweight coated paper, wherein said extended-nip, shoe calender produces a No. 5 LWC offset sheet with up to 22% bulk improvement relative to its supercalendered counterparts, while providing better brightness and opacity, as well as providing comparable or better printing performance.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a graph that illustrates the effect of calendering on caliper performance. The graph shows that papers calendered with shoe nip calender show significantly higher caliper.

FIG. 2 is a graph that illustrates the effect of calendering on brightness performance. The graph shows that samples that are finished in a shoe nip calender clearly give higher brightness than those that are finished in a supercalender.

FIG. 3 is a graph that illustrates the effect of basepaper on opacity performance

FIG. 4 is a graph that illustrates the effect of coating on gloss performance.

FIG. 5 is a graph that illustrates Parker Print Surf (PPS) performance. The graph shows that the PPS performance is not only dependent on calendering method, but also on types of basepaper and coating.

FIG. 6 is a graph that illustrates the effect of coating on print gloss measurements.

DESCRIPTION OF THE INVENTION

The process of the invention produces a low weight paper product having a relatively high bulk, therefore producing a thicker sheet of reduced density or compaction, while maintaining the benefits of higher stiffness and opacity that are comparable to that of a heavier weight sheet.

In the process of the present invention, a basepaper is produced with a high level of mechanical pulp. The process further comprises a coating formulation composed of a pigmentation containing (i) hollow plastic pigments in an amount of at least 2% by weight of the total amount of pigments (ii) platy or fine particle engineered kaolin in an amount of at least 70% by weight of the total amount of pigment, (iii) TiO_2 in an amount of at least 2% by weight of the total amount of pigment, and (iv) calcined clay in an amount of at least 10% of the total amount of pigment. Binders include 14-20 parts by weight of total pigment bi-modal particle size distribution styrene butadiene (PSD SB) latex or SB latex with Acronitrile modification. Co-binders include CMC, acrylic acid based, or associative based thickeners. The coating formulation is applied using blade coater or a metering size press at coat weights ranged from about 2.5 to 5.5 pounds/3300 square feet. The process of the present invention further comprises a calendering step, which is done using two extended-nip calendars, with one nip per side, in which the coated side of the paper faces the thermal rolls with temperature ranged from 320° F to 420° F. Line loadings are ranged from about 1400-2600 PLI. Sheet moisture prior to calendering is controlled at about or above 6.5%. The resulting paper exhibits better brightness and opacity than supercalendered counterparts. Printing performance is equivalent or better than supercalendered counterparts, specifically in print gloss performance.

FIBER FURNISH

The LWC paper, manufactured using the process of the present invention, would start with a waterborned furnish having a high percentage of mechanical pulp with the remaining makeup is Kraft. The mechanical pulp is generally about at least 40%, usually in the 40% to 80% range, and preferably in the range of 60% to 80%. The mechanical pulp portion comprises an equal blend of thermal mechanical pulp and conventional stone groundwood pulp. The remaining composition is Kraft. Mechanical pulp gives a well-formed base. As used herein, the term mechanical pulp may include stone ground wood (SGW), thermal mechanical pulp (TMP), and chemi-thermal mechanical pulp (CTMP). Sample furnish formulations are: (1) 30% TMP/30% SGW/40% softwood Kraft (SWK) and (2) 60% TMP/10% PGW 30% SWK. SWK is not considered a mechanical pulp. Another example might be 55%-65%CTMP/35%-45% SWK.

A paper sheet is created from the above furnish using conventional papermaking equipment. The paper sheet then moves into the press section wherein it can be conventionally pressed. The web is then sent through the dryer section and dried to a moisture content of below 6% and preferably to 4% or less. The paper may then be coated on or off the papermaking machine with the coating formulation of the present invention.

COATING FORMULATION

In the process of the present invention, a coating formulation is applied before finishing. The coating formulation according to the present invention comprises (i) a hollow plastic pigment; (ii) a kaolin pigment; (iii) a calcined kaolin clay; (iv) a titanium dioxide (TiO_2) pigment; (v) a synthetic latex binder; and (vi) a synthetic thickener (or a co-binder including carboxymethylcellulose or acrylic acid

based or associative based thickeners. The coating formulation may also comprise precipitated calcium carbonate (PCC) or ground calcium carbonate (GCC)

The hollow plastic pigment is in an amount of at least 2% by weight, and preferably about 3-5% by weight of the total amount of pigments. Suitable hollow plastic pigments include ROPAQUE HP-1055®, supplied commercially by ROHMNOVA 2990 Gilchrist Road, Akron, Ohio 44305. The kaolin pigment is at least about 70% by weight, and preferably 80-100% by weight of the total amount of pigment, and is preferably engineered with a fine particle size and very platy morphology. The kaolin pigment has a fine particle size distribution characterized in that at least 85% of the particles are less than 2 micron and at least 50% of the particles are about less than 0.5 microns based upon particle count using a Sedigraph particle size analyzer. The kaolin has a platy morphology characterized as both fine and coarse particles having a shape factor greater than 15, preferably about 20 to 27. Shape factor was calculated based on the method described by Sven Lohmander, "Aspect Ratios Of Pigment Particles Determined By Different Methods," Nordic Pulp And Paper Research, Vol. 15, No.3/2000, pg. 221. Suitable kaolin pigments include CONTOUR 1500®, supplied commercially by Imerys, Rt-1, Dry branch, Georgia 31020. The calcined kaolin clay is at least 5% by weight of the total amount of pigment. Suitable calcined pigments include ANSILEX 93®, supplied by Engelhard, 101 Wood Avenue, Iselin, New Jersey 08830. The TiO_2 pigment is in an amount of at least 2% by weight and preferably about 3-5% by weight of the total amount of pigment. Suitable TiO_2 pigments include RPS VANTAGE®, supplied by Dupont. The synthetic latex binder is at a concentration of at least about 12 or more parts by weight of the total amount of pigment. Suitable synthetic latex binders include STYRONAL 4681®, supplied commercially by BASF, 11501 Steele Creek Road, Charlotte, North Carolina 28273. The synthetic thickener is at a concentration of at least about 0.05 parts or more by weight of the total amount of pigment (or a co-binder including carboxymethylcellulose (CMC) or acrylic acid based or associative based thickeners). Suitable synthetic thickeners include STEROCOLL FD®,

supplied commercially by BASF. The coating formulation may also comprise PCC or GCC. Supplied commercially by Minerals Technologies, Inc., 9 Highland Avenue, Bethlehem, Pennsylvania 18017 and Omya, 61 Main Street, Proctor, Vermont 05765.

The coating formulation may be prepared by mixing together the various ingredients in a one-tank make down or by pre-mixing then combining separate ingredients. The mixture is generally agitated to homogenize the ingredients. The resulting formulation may be of a viscosity ranging from about 1000 cPs to about 1500 cPs, measured by a Brookfield viscometer at 100 rpm. The solids content of the coating formulation when it is used, for example, in a blade coater, may desirably be as high as from about 53% to about 55% by weight; however, because the plastic pigment is typically added to the formulation in the form of an aqueous dispersion having a low solids content, the solids content of the coating formulation is more usually in the range of about 49% to about 51% by weight. A sample coating formulation is:

91% CONTOUR 1500®,
5% RPS VANTAGE®,
4% ROPAQUE HP-1055®,
14 parts STYRONAL 4681®, and
0.7 parts STYROCOLL FD® at 50% coating solids and 1000 cPs Brookfield viscosity.

The coating formulation should be applied at a weight of about 2.0 to 6.0 pounds/3300 square feet, and preferably 2.5 to 5.5 pounds/3300 square feet. The coating formulation is generally, but need not be, applied to both sided of the paper web. Generally, the coating formulation can be applied with any conventional type blade coating as shown in U.S. Pat. Nos. 4,250,211 and 4,512,279, and/or a fountain type coater shown in US Pat. No. 5,436,030 and/or a double bladed coater as shown in US Pat. No. 5,112,653, the teachings of

which patents are incorporated herein by reference. In addition, the coating formulation can be applied using a metering size press, such as the Metso's Optisizer. The term blade or blade coater as used herein, unless specifically stated, is understood to include such other equivalent metering techniques. The doctor blade shown in US Pat. No. 4,780,336 has been advantageously used to provide low coat weight. Preferably, the coating formulation is applied using a blade coater, in a substantially uniform thickness over the surface of the base stock. Preferably, the coating process is carried out off-line or in-line. Prior to calendering, the coated web has a moisture content greater than 5.5%, preferably 6.5%, most preferably 7.0%.

EXTENDED-NIP CALENDER

The coated paper can then be calendered, using two extended-nip calenders, preferably using a shoe nip calender (SNC), that comprises a heated roll and a soft shoe backing, as shown in U.S. Patent Nos. 6,332,953, 6,465,074 and 6,213,009 the teachings of which patents are incorporated herein by reference. In this type of calender the nip is formed between a cylindrical press roll and an arcuate pressure shoe. The latter has a cylindrically concave surface having a radius of curvature close to that of the cylindrical press roll. When the roll and shoe are brought into close physical proximity to one another, a nip, which can be five to ten times longer in the machine direction than one formed between press rolls, is formed. This increases the so-called dwell time of the cellulosic fibrous web in the long nip while maintaining an adequate level of pressure per square inch of pressing force. The use of a shoe nip calender preserves significantly more of the original bulk than traditional supercalender or hot soft calenders.

The coated paper passes through the two calendering nips, with each side of paper facing a heated roll and treated with one of said calender nips; each calendering nip being formed by a calender roll having a surface temperature of

at least 300° F and a backing shoe having a width of at least 30 mm, the nip providing loading of at least 1000 pounds per linear inch; the calendered paper having a caliper preservation greater than 75%.

The resultant coated paper will generally have the following characteristics as compared to conventional coated paper of the same weight:

(1) up to 4.0% higher brightness
(2) up to 3.3% higher opacity;
(3) Up to 22% higher caliper;
(4) 1%-7% lower paper gloss but comparable or 2%-5% higher print gloss;
(5) slightly rougher surfaces, that is, 1.6-2.6 microns as measured by PPS, at 10Kg clamping pressure. (Commercially acceptable PPS of 1.6-1.9 microns, were obtained using coatings A or B below.)
(6) lesser weight per roll for the same roll diameter, evidencing the higher bulk of the paper

EXAMPLES

BASEPAPER

The effect of five 32 g/m^2 basepaper was examined using the following types of basepaper: B1, B1/hi-mechanical, B4 and two hot soft pre-calendered basepaper (B1/precalendering and B1/hi-mechanical/precalendering). The properties of the B1 and B1/hi-mechanical basepaper are shown in Table 1. B4 basepaper is similar to B1 basepaper, except that the B4 has less addition of wet-end starch in the sheet. Precalendering basepaper has smoother surfaces than non-precalendered basepaper, but its caliper is reduced. Table 1 shows that by increasing TMP content from 30% to 60% the total mechanical pulp content increases from 60% to 70%, while still maintaining good paper machine runnability. Table 2 shows that by increasing the amount of mechanical pulp from 60% to 70% the caliper increases from 2.85 to 3.03, while roughness and porosity are slightly increased.

COATING FORMULATIONS

The "control" coating is a typical No.5 lightweight coating, consisting of: 79% standard delaminated kaolin with 80% less than 2 micron and a median particle size of 0.75 microns using a Sedigraph particle size analyzer; 7 % of 93% brightness calcined kaolin, 7.5% TiO_2; 6.5% of a hollow plastic pigment; 8 parts starch; and 12 parts styrene butadiene (SB) latex at 50.7% coating solids.

Coating A consists of 86% fine platy kaolin with 90% less than 2 microns and a median particle size of 0.5 microns using a Sedigraph particle size analyzer; 5.5% of a hollow plastic pigment; 14 parts latex containing styrene butadiene with acronitrile monomer (SBAn); and 0.25 part of synthetic thickener at 53.9% solids.

Coating B consists of 76% a coarse platy delaminated kaolin with 60% less than 2 microns and a median particle size of 1.6 microns; 10% of 93% brightness calcined kaolin; 8.5% of TiO_2; 5.5% of a hollow plastic pigment; 12 parts SBAn latex; and 0.25 part of synthetic thickener at 51.1% solids.

Coating C consists of 86% fine engineered kaolin with 99% less than 2 microns and a median particle size of 0.21 microns; 8.5% of TiO_2; 5.5% of a hollow plastic pigment; 16 part of SBAn latex; and 0.25 part of synthetic thickener, at 55.6% solids.

COATING PROCESS

Using a shortdwell blade coater, the coatings, as described Table 3 below, were applied on the basepapers shown in Tables 1 and 2. The coat weights were targeted at 5.7 g/m^2 on the wire side of paper and 4.9 g/m^2 on the felt side of paper. The wire side was coated first and followed by felt side. With the exception of the B4 basepaper, which was coated at 3700 fpm, all the

basepapers were coated at 2100 fpm. The final coated sheet moisture content was controlled at 5.5-6.0%.

Table 1 - Basepaper Properties

	B1 Std	B1/hi-mechanical
Furnish	40 Kraft, 30 TMP, 30 GWD	30 Kraft, 60 TMP, 10 GWD
Other Furnish	18 Coated Broke, 5 Return Broke	5 Coated Broke, 5 Return Broke
Rawstock Ash (%)	5.7	3.1
Porosity(s)	21	23.7
Smoothness (SU) Top/Wire	235/292	245/299
Formation	29.9	31.3
Opacity (%)	75.8	75.2

Table 2 - Basestock Comparisons

Basestock	Caliper(mils)	Gurley Porosity(s) Mean/S.D.	PPS10kg Wire Side	PPS10kg Felt Side
B1	2.85	20.2/3.1	8.11	6.26
B1/Pre-Calendering*	2.19	25.8/2.6	4.89	3.84
B4	2.50	22.9/2.9	5.56	5.63
B1 with hi-Mechanical	3.03	25.5/2.8	8.52	6.56
B1 with hi-Mechanical And pre-Calendering*	2.46	27/2.5	6.05	4.86

*Hot soft pre-calendering was done using one nip per side at 350° F and 15psi

Table 3 - Coating Formulations

	CONTROL (BLADE)	A (BLADE)	B (BLADE)	C (BLADE)
Standard delaminated	79			
Fine platy		86		
Coarse platy			76	
Fine engineered				86
Ansilex 93	7		10	
TiO_2	7.5	8.5	8.5	8.5
Ropaque 1055	6.5	5.5	5.5	5.5
SB Latex	12.5			
SBAn Latex		14	12	16
Starch	8			
Thickener No. 1		0.05	0.05	0.05
Thickener No. 2		0.2	0.2	0.2
Coating Solids(%)	50.7	53.9	51.1	55.6

<u>CALENDERING PROCESS</u>

The above-coated papers were calendered at 3000 fpm using the Optidwell shoe-nip calender, manufactured by Metso Paper Inc. The calendering process was done one-nip-per-side with the wire side calendered first and followed by felt side. The thermal roll temperature for the first nip was 350° F and 70 mm nip width; the 2nd nip was 400° F and 70 mm nip width. The loading for the 1st and the 2nd nips was 2300 pli.

In addition, the papers coated with the "control" coating were also calendered using a conventional supercalender at 1000 fpm. The supercalendering roll temperature was at 190° F and nip loading was adjusted so that a 45% sheet gloss can be obtained with the B1 basepaper sample. The

same supercalendering conditions were also used with the B4 basepaper that was coated with the "control" coating.

COATED PAPER PROPERTIES

All coated sheet properties are shown in Figures 1-6. Printing performance was assessed using a four-color web offset press at Rochester Institute of technology (RIT), Rochester, NY. Several commercial 30 pounds products were also printed at RIT for comparison purposes. Typical 32 pounds to 40 LWC paper properties, or industry averaged properties, were also summarized and included in the figures for comparisons.

CALIPER (FIGURE 1)

Samples made with the B1 and B4 basepaper, coated with the "control" coating and calendered in a supercalender showed 1.80-1.83 mils caliper, in line with that of commercial products made with the same basepaper and coated with the "control" coating. The same samples calendered in a shoe nip calender showed significantly higher caliper (2.18-2.20 mils), which is approximately a 22% improvement. The 30-pounds SNC coated samples prepared with the B1/hi-mechanical basepapers have the highest caliper, equal to or marginally better than that of a typical 40 pounds LWC product. The 30-pounds SNC coated samples prepared with the precalendered papers have lower caliper than their uncalendered counterparts, but are still in a range of typical 36-38 pounds LWC products. The 30-pounds SNC coated samples prepared with the B1 basepaper have caliper close to a typical 40 pounds LWC sheet. The 30-pounds SNC coated samples prepared with the B4 basepaper have slightly lower caliper than those prepared with the B1 basepaper, but are comparable to a typical 38 pounds LWC sheet.

Compared to samples that were coated with either coating A or coating C, samples that were coated with coating B, consisting of a coarse platy kaolin and a calcined kaolin, have improved caliper. Overall, the 30-pounds SNC papers, regardless of whether they are made with precalendered basepaper or not, have significantly improved caliper, that is, caliper is 17-27% higher than that of a supercalendered counterparts (30 pounds). As shown in Figure 1, the main contributor of the significantly better caliper is the superior bulk preservation of the shoe calender. Thus, increasing initial bulk of the paper along with the use of the shoe calender can produce the highest final caliper.

In summary, Figure 1 shows that the samples that were calendered using a shoe-nip calender and that were coated with the "control" coating exhibited about 22% higher caliper than their supercalendered counterparts. The samples that were calendered using a shoe-nip caldender and that were coated with either coating A, B, or C, exhibited about 12-22% higher caliper (2.12-2.32 mils caliper) than the highest-caliper commercial sheet that was used for the comparison, that is, the 30# Mainebulk. The effect of coating formulation on bulk was relatively small with only the samples that were coated with coating B producing a marginally higher bulk. The effect of basepaper on bulk was largely expected, that is, precalendered basepaper produced a lower caliper and a higher mechanical pulp containing basepaper produced a higher bulk. Overall, the B1/hi-mechanical basepaper gave the highest bulk, and followed by B1 basepaper, B4 basepaper, B1/hi-mechanical/precalendering basepaper, and then B1/precalendering basepaper.

BRIGHTNESS (FIGURE 2)

The higher caliper of noncalendered basepapers produce a higher brightness than precalendered basepapers. When compared the samples that were coated with the "control" coating, the samples finished in SNC clearly have higher brightness than supercalender samples. This is due to the relatively mild

pressure and significantly fewer nips of the shoe nip calender. Samples that were coated with either coating A or coating B have similar brightness performance and are better than samples that were coated with coating C. In general, the brightness of the SNC samples is in a range of 72.7-74.5%, which is significantly better than the commercial samples (30 pounds) as well as industry samples (32-40 pounds).

In summary, Figure 2 shows that the shoe-calendered papers coated with the "control" coating exhibited about 1.1-3.1 points higher brightness than their supercalendered counterparts. Substituting the "control" coating with coating A produced 0.2-0.6 points higher brightness. Samples that were coated with coating B produced comparable brightness. Samples that were coated with coating C produced 0.3-0.5 points lower brightness. Increasing the mechanical pulp in the basepaper reduced brightness. Precalendering basepapers gave comparable or slightly better brightness than their non-precalendering counterparts. Overall, superior brightness was obtained with the samples that use B1, B1/precalendering, or B1/hi-mechanical/precalendering basepapers and that were coated with either coating A or coating B.

OPACITY (FIGURE 3)

Similar to brightness performance, opacity is also highly dependent on the type of basepaper. The uncalendered basepapers (B1 and B4), specifically those with higher mechanical pulp content, produce a higher opacity. Samples coated with either coating A or coating B (both consisting of platy kaolin) have similar opacity and both give higher opacity than the samples that were coated with coating C or sample that were coated with the "control" coating. Except for the samples coated with coating C and made with the B4 basepaper, the opacity of the SNC samples is significantly better than the commercial samples (30 pounds) and the industry samples (32-40 pounds).

In summary, Figure 3 shows that the shoe-calendered papers that were coated with the "control" coating exhibited about 2.0-2.5 points higher opacity than their supercalendered counterparts. Substituting the "control" coating with either coating A or coating B on basepapers (including B1, B1/precalendering, B1/hi-mechanical, and B1/hi-mechanical/precalendering basepapers), produced about 1 point higher opacity than samples that were coated with coating C, which produced about 1 point lower opacity. Precalendering bases produced 0.1-0.8 points lower opacity than their non-precalendering counterparts. Overall, samples that were coated with coating A and made with the B1/hi-mechanical basepaper gave the highest opacity, followed by those sample that were coated with either coating A or coating B and made with the B1, B1/precalendering, or B1/hi-mechanical/precalendering basepaper.

75° TAPPI SHEET GLOSS (FIGURE 4)

Samples coated with the "control" coating that were finished in a SNC have a significantly lower gloss than those that were finished in a supercalender. In fact, the SNC samples only have 31-33% gloss, significantly lower than 30 pounds commercial samples. Further, the gloss performance of the starch-containing "control" coating is poorer than the non-starch-containing coatings A, B, and C. The only samples that were able to reach 40% gloss were those that were coated with either coating A or coating C. In general, the smoother surfaces and lower porosity of B4 and precalendered basepapers gave improved sheet gloss. Samples that were prepared with B4 basepaper and coated with coating C had the highest gloss (50%)..

In summary, Figure 4 shows that the shoe-calendered papers coated with the "control" coating exhibited about 15-20 points lower paper gloss than their supercalendered counterparts. Substituting the "control" coating with coating A produced about 9-12 point higher paper gloss; substituting with coating B, produced about 2-5 points higher paper gloss; and substituting with coating C,

produced about 12-17 points higher paper gloss. Precalendering produced 2-5 points higher sheet gloss. Overall, papers coated with coating C have higher gloss than those coated with coating A, and papers coated with coating B have the lowest paper gloss.

SURFACE SMOOTHNESS AS MEASURED BY PARKER PRINT SURF (FIGURE 5)

Samples that were coated with the "control" coating, and that were finished in a SNC have poorer Parker Print Surf (PPS), or rougher surfaces, than those that were finished in a supercalender. The PPS performance is not only depending on calendering method, but also on types of basepaper and coating. For example, a rougher basepaper like the B1 basepaper, gives poorer PPS than a smoother basepaper like the B4 paperpaer. For the same reason, precalendering which improved the smoothness of the basepaper also improves the PPS compared to uncalendered basepapers. The coatings A and B, consisting of platy kaolin, give better PPS than coating C consisting of fine-engineered kaolin. Thus, SNC samples give poorer PPS than commercial samples (30 pounds) as well as average industry samples (32-40 pounds).

In summary, Figure 5 shows that the shoe-calendered papers coated with the "control" coating exhibited about 0.1-0.9 points higher PPS than their supercalendered counterparts. Substituting the "control" coating with coating A reduced PPS by about 0.1-0.6 points. Substituting with coating B reduced PPS by about 0.1-0.4 points. Substituting the "control" coating with coating C gave 0.2-0.3 points higher PPS. Precalendering reduced PPS by 0.1-0.5 points. Overall, all basepapers coated with either coating A or coating B gave commercially acceptable PPS, that is, 1.6-1.9 microns.

PRINT GLOSS (FIGURE 6)

The print gloss is measured on a four-color black area using a RIT web offset press print signature. When compared to samples coated with the "control" coating, it is found that supercalendered samples have higher print gloss than SNC samples, largely due to the higher sheet gloss of supercalendered samples. Print gloss performance, similar to sheet gloss, is also dependent on the smoothness and porosity of basepapers, that is, the smoother surfaces and lower porosity of the B4 and precalendered basepapers give improved print gloss. Coatings A, B, and C give better print gloss than the "control" coating. SNC samples in general exhibit comparable or better print gloss than 30 pounds commercial sheets. Among all SNC samples, the samples that were prepared with the B4 basepaper and were coated with coating A exhibited the highest print gloss.

In summary, the shoe-calendered papers coated with the "control" coating exhibited about 7 points lower print gloss than their supercalendered counterparts. Substituting the "control" coating with coating A gave 10-12 points higher print gloss; 4-8 points higher with coating B; and 4-10 points higher with the coating C. Precalendering produced 1-5 points higher print gloss. Overall, the shoe-calendered papers that are coated with either coating A, B, or C gave at least comparable print gloss to commercial sheets.

Although the invention has been described with reference to preferred embodiments, which should be construed in an illustrative and not limiting sense, it will be appreciated by one of ordinary skill in the art that numerous modifications are possible in light of the above disclosure. For example, different latex and pigments may be used. All such variations and modifications are intended to be within the scope and spirit of the invention.